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THE OIL INDUSTRY IN THE EAST INDIES

AN ACCOUNT OF DENIAL AND RECONSTRUCTION WORK IN THE PROPERTIES OF THE ROYAL DUTCH-SHELL GROUP

By M. J. DE BLANK*

THE disastrous impact of the war on the oil industry in the East Indies, and the difficulties with which reconstruction plans have had to contend are most clearly shown by the fact that even now, nearly two and a half years after the end of the war with Japan, production is only about 50 per cent of the pre-war figure of 9,000,000 tons annually. It is the purpose of this article to review briefly the events of the last six years in the East Indies, and to show how the oil industry in that area and the Royal Dutch-Shell interests in particular, have been affected by two series of denial measures, by fighting and bombing, by uneconomic operation and emergency repairs, and finally by widespread disturbances in the Dutch territories.

THE POSITION IN 1941

There are five main oil producing areas and several subsidiary areas. The crude oil varies greatly from the crudes of Northern Sumatra, containing virtually no fractions heavier than kerosine, to the Tarakan crude, containing nothing lighter than gas oil. Similarly crudes of all types, asphaltic, paraffinic, aromatic, and mixed are all found in different parts.

The Royal Dutch-Shell Group had the following main sources of production, and refineries:

* N. V. de Bataafsche Petroleum Maatschappij.

NORTHERN SUMATRA

The Rantau, Paloeh Taboehan, and Poeloe Pandjang fields served by a refinery at Pangkalan Brandan with a capacity of 3000 metric tons per day.

SOUTHERN SUMATRA

Talang Djimar, Tempino, Badjoebang and Kenali Assam fields all connected by pipeline to the refinery at Pladjoe, which had a daily capacity of 7000 tons.

SOUTH-EAST BORNEO

Louise, Sanga Dalam, Moeara, and Anggana fields connected by pipeline to Balikpapan, where the refinery had a capacity of 7500 tons daily.

NORTH-EAST BORNEO (Tarakan)

Pamoesian field had a daily production of 1400 tons and was connected by pipeline to the ocean terminal at Lingkas. No refinery was needed for this crude, which has a high flash-point and can be used without processing.

NORTH-WEST BORNEO (Sarawak and Brunei)

Seria and Miri fields were both connected by pipeline to the refinery at Lutong, which had a daily capacity of 2700 tons.

JAVA

The most important field was Kawengan, but a number of smaller fields were also in operation. Most of the crude was refined at Tjepoe (daily capacity 1500 tons). About 3000 tons monthly were shipped to Balikpapan via Surabaya for refining. A small part of the production was refined at Wonokromo near Surabaya (capacity 250 tons daily).

CERAM

Boela and Lemoen fields are partly under the sea. The 250 tons produced daily were shipped to Balikpapan for refining.

DUTCH NEW GUINEA

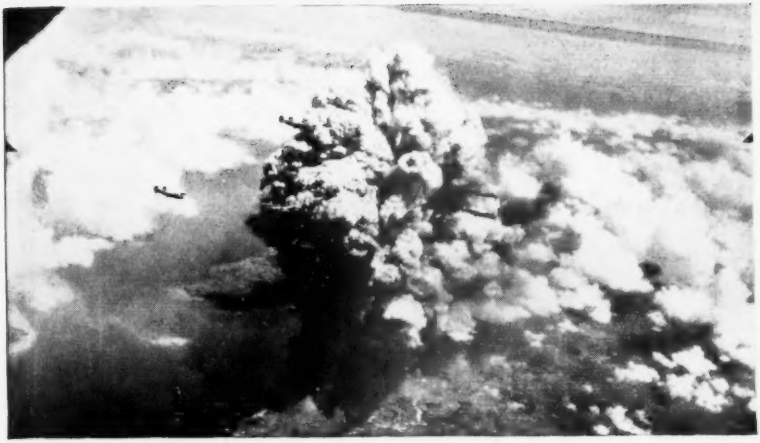
Oil had been found at Klaimono and other places but there had been no commercial production.

REFINERIES

The plants at Pangkalan Brandan, Pladjoe, and Balikpapan were all full-scale refineries with distilling, extraction and treating units for all main products. In addition Balikpapan had lubricating oil, grease, and asphalt plants. The refineries at Lutong, Tjepoe, and Wonokromo were on a smaller scale designed to treat the crude produced in their areas.

ALLIED DENIAL MEASURES

The dangers of Japanese expansionist policy had not been ignored either by the authorities in the Dutch colonies or by the British officials administering the native states of Sarawak or Brunei.



Bombing of the Balikpapan installations in October 1944. The Liberators seen in the foreground are flying at about 20,000 feet.

When the blow fell, preparations to meet all eventualities were already well in hand, and were pressed forward. Detailed plans for demolition had been prepared by the military authorities with the technical advice of oil company personnel. Generally, more than one plan was evolved for each series of operations to allow for the various periods of time (2–24 hours) which might be available for the work of destruction. The executive orders for the enforcement of these schemes were in all cases to be given by the military commanders, and the demolition was to be carried out under their guidance.

Complete instructions and detailed time-tables were drawn up for each demolition squad in such a way that the work carried out by one squad would not endanger or impede the operations of others, and so that, upon completion of their tasks, each could retreat to an assembly-point before leaving the area. Preparations which could be made without affecting normal operations, for instance the installation of receptacles for explosive charges and of fire-boxes in the firewalls of tank farms, were all made well in advance; in other cases, where it was necessary for the implementation of the plans, operations were discontinued. Generally, normal work had, in fact, ceased well before the final orders for demolition were issued.

As far as the surface equipment of oilfields was concerned, all the vital parts of installations which were not in operation nor required for the execution of the denial schemes—magnetos, atomizers, fuel pumps of diesel and gas engines, gauges, meters, slide-valves of steam engines, etc.—had been removed and collected at places where they could effectively be destroyed. The explosive charges, which were available from seismic operations, were placed in position, and electrical wiring and fuses prepared for firing, but not connected to the detonators. Holes were made in certain firewalls of tank farms so that the burning oil would flow towards the installations. Important files and documents had already been sent away, and the working records that remained were bundled up ready for destruction; great care was taken that no field maps should fall into enemy hands.

The destruction of much equipment was effected by removing, by means of oxy-acetylene torches, water-jackets, cylinders, axles, crankshafts, etc.; electrical instruments and compressor components were smashed with heavy hammers; engines were run without lubricating oil or coolant and boilers were fired empty. Explosives were used to blow up crude oil transportation pumps, gas compressor centres, central pumping plants, machine shops and electric power stations. Oil in main tank farms was set alight, and stores and jetties razed by fire. Pipelines between the fields and refineries were blown up at several points, particularly at river-crossings, and in some cases, at Pladjoe for instance, highly waxy oil was pumped into pipelines and left to congeal.

For the wells themselves preparations had been put in hand for cementing plugs above the perforations in such flowing wells as were not required for current operation. In some major fields, plans had been made to cement the tubing in flowing wells; in certain cases the wells had first been "killed" with mud or water. In pumping, and in some flowing, wells the tubings were pulled to about 50 m from the bottom (or 20–30 m in the case of certain shallow wells) and suspended on the well-head by means of a clamp which could be knocked away with a sledge hammer, so as to cause the tubing to drop into the well. A selection of small articles—wrenches, cones of rock-bits, a few sacks of cement and barytes—were placed near the well-head in readiness to be thrown in after the tubings had been dropped. Finally, a tin containing four blocks of trotyl—two pounds in all—was placed available, together with detonator and fuse, to be dropped on top of the tubing and exploded to destroy the water-string at that point. Flowing wells were provided with a heavy charge of explosives at the well-head in order to blow it off, and so fire the escaping oil and gas.

The gradual closing in of wells during the month before the order for final destruction was given, made it possible, in many cases, to improve upon the original plans.

In the case of Sarawak important equipment at Lutong refinery and at the oilfields had been dismantled before the war started and sent to Singapore for shipment overseas.

The plans for the destruction of refineries and tank installations laid down that the oil in the main tank farms was to be set on fire and the wharves and stores were to be overrun by burning oil. Explosive charges were to be attached to the principal pumps, compressors, boilers and stills and all prime movers were to be destroyed. Furnaces and stills were to be wrecked by heating them dry. In some cases explosive charges were to be attached to distillation columns. Instruments, etc., were to be broken up with hammers. Stocks of packed products were to be partly opened and then set on fire.

The stocks of crude oil and products destroyed at the outbreak of hostilities in the East Indies are estimated at about 1,000,000 metric tons.

The dates on which the destruction was started at the various installations were:

December	8, 1941:	Seria, Miri, and Lutong in Sarawak;
January	10, 1942:	Tarakan;
,,	20, 1942:	Balikpapan and its oilfields;
,,	26, 1942:	Babo (New Guinea);
,,	26, 1942:	Boela (Ceram);
February	11, 1942:	P. Bukom and P. Samboe;
,,	12, 1942:	P. Brandan and P. Soesoe and oilfields;
,,	14, 1942:	Pladjoe and its oilfields;
March	1, 1942:	Tjepoe and its oilfields.

The destruction in all cases was reported carried out according to plan without accident to employees and to be very thorough and successful. Only in Pladjoe was the demolition of the

Destruction by the Japanese of the high vacuum installation at Balikpapan.

refinery incomplete, as it was greatly hampered by the dropping of Japanese paratroops; some damage, however, was done, which was increased during the fighting that followed and subsequent bombing.

In most cases the demolition was effected very shortly before the attack by Japanese forces. In the Brandan area, however, the Japanese did not attack until March 1942 and denial measures could therefore be effected without any interference.

THE JAPANESE OCCUPATION

The Japanese expected that the installations would be destroyed and the invading forces were accompanied by the necessary technical personnel and materials to effect repair work. One of the Japanese paratroop officers who landed on Pladjoe refinery, for instance, when he gave orders to stop the reforming unit, remarked to one of the still men that the feeding pump must be stopped because it had lost suction.

In Balikpapan and Tarakan the Japanese arrived with fifteen freighters loaded with a very complete and varied selection of materials which enabled them to produce without delay the necessary steam and electric power needed in the rehabilitation work. They had with them several complete motor- or electrically-driven drilling outfits. In addition, they could, of course, press the natives that were left behind to work for them. It happened, however, that a ship loaded with many Japanese oil industry technicians and experts was torpedoed and sunk early in 1942 with a considerable loss of life.

The following table gives some information about the amounts of crude oil produced in the East Indies during the Japanese occupation.

Total amounts of crude oil extracted by the Japanese

	1942	1943	1944	1945	Total
		In 1000 metric tons			
Pladjoe	497	1,655	1,615	564	4,331
Pangkalan Brandan	213	757	512	202	1,684
Balikpapan	247	656	301	143	1,347
Tarakan	196	537	366	—	1,099
Miri-Seria	219	608	690	79	1,596
Tjepoe-Wonokromo	151	453	386	170	1,160
Ceram	—	—	—	—	125
Total (including NIAM)	1,523	4,666	3,870	1,158	11,342

The distribution over the years has been estimated.

The quality of the products manufactured from these crudes was, however, considerably lower than before the war, as in many cases the Japanese could not rebuild the installations or did not "know how" to operate them properly. In certain cases new installations were built; for instance, a carbon black plant, a steel plant to make ingots from the scrap and steel obtained from destroyed installations, and a new synthetic lubricating oil plant, etc. In Borneo several saw mills were installed mainly to obtain wood for shipbuilding.

Proof that the Japanese were none too successful in their manufacture of products is provided by their efforts at several places to install factories to make alcohol from cane sugar, for blending with gasoline to improve the octane number.

The Japanese Army and Navy

Some of the 5000-cu.m. tanks after the Allied landing at Balikpapan.

divided the Indies between them on the basis of landing strength and not on the basis of the quantities of products each service would need. The navy obtained the oil facilities on the East Coast of Borneo (Balikpapan and Tarakan), while the army acquired all the facilities in Sumatra, Java, and the West Coast of Borneo (Seria, Miri, Lutong). The problems that arose because the army had control of about 85 per cent of the oil production, while the navy was the larger consumer and controlled the majority of the tankers, were settled by an army-navy committee with headquarters in Tokyo. Local army and navy representatives met regularly in Singapore to implement the directives sent down from Tokyo and to arrange the allocation of products, of shipping, and of convoys.

The Japanese had to ship the oil products manufactured in the East Indies to the home islands and to their outlying garrisons in the Pacific. About three-quarters of the Japanese tanker fleet was allocated to the task of moving oil products from the Indies to the inner zone. Shipbuilding was considered an essential war industry in Japan and was given priority in construction materials and labour. The importance of oil and tanker transport to the Japanese war effort was early recognized by the Allies, and oil tankers therefore were given a high priority as targets for submarines. In the beginning this did not have much effect, since the American naval bases were too far away from the regular Japanese shipping lanes, except for those to the outlying Japanese bases in the Pacific. It was not till the attacks in the South-west Pacific started gaining momentum, and bases were acquired closer to the Philippines and Japan, that the sinking of tankers exceeded tanker construction. This loss of tankers seriously affected Japanese fleet movements and naval strategy. The Japanese did all they could to prevent such losses, keeping close to the coast of China so that the ships could be protected by air, organizing well-protected convoys, sailing mostly during the night and hiding during the day. These measures, however, aggravated the position, since they all resulted in longer turn-around time for tankers.

The table above reflects the decrease in production dictated by Japanese inability to ship away products from mid-1944 onwards owing to the success of Allied attacks on Japanese tankers.

After the invasion of the Philippines the shipping position became even more hopeless, as the shipping lanes from the south were almost completely cut off. Reduction in production at Tarakan started in July 1944. By September 1944 Tarakan produced only about

11 per cent monthly of what it had produced early in 1944. A similar situation existed at other oilfields and refineries, and it is reported that the last tanker convoy left Singapore for Japan in March 1945.

Early in the war Japanese operations in Ceram had to be stopped or at least were very seriously hampered by regular air bombing attacks from airfields near Darwin in North Australia.

The first aerial photographs of Balikpapan were obtained in August 1943 and showed considerable rebuilding and new construction by the Japanese. Also photos taken somewhat later of Sourabaya showed that Wonokromo refinery had been rebuilt. The distance from Darwin to the nearest refineries in Borneo (Balikpapan) and Java (Wonokromo) is about 1200 miles and one can imagine how many difficulties were involved in bombing targets at such a distance from base when the trip there and back had to be made over enemy territory and large expanses of water.

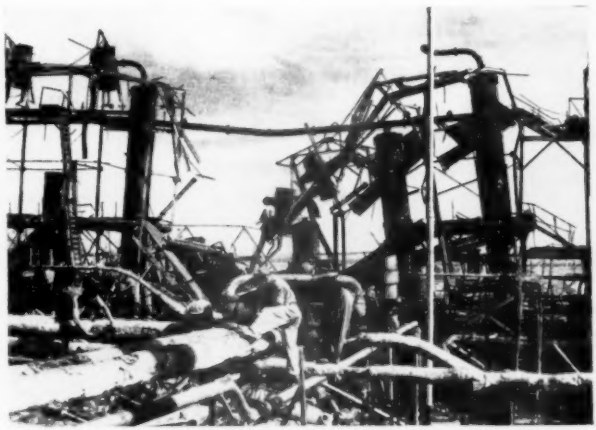
It was not until October 1944 that some very heavy allied air attacks were made on oil targets in Borneo and in the next few months considerable damage was done to the installations at Balikpapan, Tarakan, and Lutong. Some attacks in 1944 on Wonokromo refinery resulted in serious destruction and the Japanese decidedtorebuild the distilling unit in a native village (Bendoel), about 1 km south of the refinery. This unit was very well-camouflaged and dispersed amongst the trees and palms. Late in 1944 and early in 1945 a few bombing raids were made on Pladjoe and Pangkalan Brandan refineries and on the N.K.P.M. (Standard of New Jersey) refinery at Soengei Gerong near Palembang by Super-Fortresses based on India and Ceylon. Especially at Pangkalam Brandan serious damage was done.

Mines also were laid regularly by plane or submarine in harbours and narrow shipping lanes, which seriously hampered shipping movements.

Early in 1945, however, the shipping situation was already very difficult for the Japanese and there was no further need for air attacks on oil installations in the East Indies until the commencement of the Allied invasion.

ALLIED INVASION AND RECONSTRUCTION

The first oil centre to be recaptured was Tarakan, where a landing took place on May 1, 1945. Prior to the attack considerable damage to the tank installation at Lingkas was done by Allied bombing and shelling in order to



The crude oil distillation battery at Balikpapan—reconstruction work is in progress in the foreground.

prevent the Japanese from using burning oil as a defence against landings. During the subsequent fighting more installations were damaged, but the principal destruction, particularly to the wells and drilling equipment, was done by the Japanese shortly before the invasion. The methods used by them were similar to the ones we ourselves used in our denial schemes, and on the whole the destruction carried out by the Japanese gave more trouble during reconstruction than the results of Allied bombing.

The same applies to the oilfields at Seria and Miri and the refinery at Lutong, where the invasion started in June, 1945, and to Balikpapan, where the Allied forces landed on July 1, 1945.

Although the destruction caused by the Allied offensive and the Japanese denial measures has been very serious, we have been able to find a certain amount of equipment and material that was not damaged or which could be repaired easily and used again during the first stage of rehabilitation. Upkeep of the establishments under the Japanese occupation had been very poor and the first impression received from the installations after recapture was one of serious neglect.

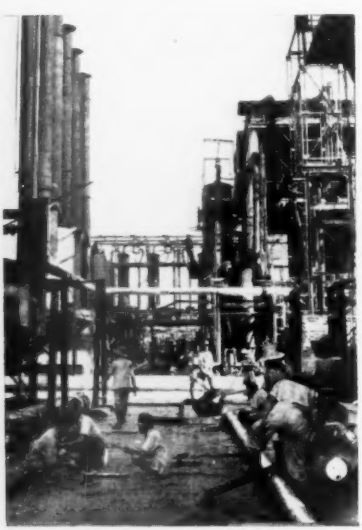
The first part of the installation to be repaired at Balikpapan was the machine shop, where the first six machine tools were operating again by August 6, 1945. As prime mover we used two small diesel engines which were found in the machine shop where they had been left by the Japanese for overhaul. The first electric power used in the machine shop was obtained from some diesel-driven generators which had been used by the Japanese for searchlight installations. After part of the machine shop was operating again, two Trumble distilling units were repaired and on July 3, 1946, the first distilling unit was started again on Louise crude oil.

Work at the oilfields near Balikpapan could not be started until after the liberation and both at Louise and Tandjoeng primitive distilling units were found making oil products for local demand.

In the meantime, at the oilfields north of Balikpapan, a certain number of wells had been repaired and the pipelines from the fields to Balikpapan had been partly renewed.

An extra difficulty encountered at Seria was the fact that the Japanese had set several wells on fire, and these had to be extinguished with the primitive means, mostly improvized, which the engineering unit had available.

In addition to items found locally and used in the first stage of rehabilitation, large quantities of material had been accumulated in Australia and elsewhere for the later stages, and expert technical staff held in readiness, and it was due to this foresight that rehabilitation has been advanced as far as it has in the areas to which it has been possible to obtain access. Tarakan and Seria shipped their first cargo of crude oil in October 1945 and February 1946



Reconstructing the Trumble plants at Balikpapan.

respectively. At Tarakan, Seria, and Balikpapan several repair strings are permanently engaged in improving the existing wells in order to overcome as far as possible the consequences of Japanese neglect. In addition, drilling has been resumed. Work is, however, everywhere impeded by lack of materials and means of transport. Also the native staff is much reduced in number and quality as compared with pre-war conditions.

Camouflaged receiving tanks at the Bendoel (near Wonokromo, Sourabaya), distillation unit built by the Japs. The tanks were well dispersed and practically completely underground. The picture was taken in 1946 after trees, etc., had been cleared.

Notwithstanding all these difficulties the following production figures were attained in Borneo at the end of 1947:

Seria oilfields, 213,000 m. tons monthly
Tarakan oilfields, 26,000 m. tons monthly
Balikpapan oilfields, 31,000 m. tons mon.

The total of 270,000 tons monthly compares with 150,000 tons monthly from the same fields under Japanese occupation in 1943 and with a total output in Borneo of 200,000 tons monthly before the war. This increase has been achieved despite the difficulties of procuring materials, and of transport and man-power.

Remarkable progress has been made in the Seria field in British Borneo, where the current rate of production is about treble the pre-war output. By contrast, the disturbed conditions over a large part of the Netherlands East Indies has resulted in the Group's production in the N.E.I. as a whole (i.e., including Dutch Borneo) standing at the end of 1947 at about 170,000 tons monthly, being about one-third of the pre-war rate of output.

The refining facilities of the Royal Dutch-Shell Group in Borneo at the end of 1947 had a capacity of:

Lutong 120,000 metric tons monthly
Balikpapan 35,000 metric tons monthly

A new refinery is being erected at Muara in British Borneo and plans are now in hand for reconstructing the plant at Balikpapan.

As a result of the war ending suddenly with the capitulation of the Japanese in August 1945, no further damage was done to the oil installations in Sumatra and Java. According to the agreement reached at Rangoon in August 1945, between the Supreme Commander of S.E.A.C. and the Japanese, the latter were given the task of guarding vulnerable oil installations till these could be taken over by the Allies. This situation persisted for a considerable time since, owing to political difficulties, the handing over of the establishments was delayed.

In South Sumatra, British troops took over part of the task of guarding the refineries, at Pladjoe and Soengei Gerong about the end of July 1946, but not until September 1946 did the last Japanese troops leave these refineries.

During the period of Japanese occupation the oil installations in South

Sumatra were run by one unit, the so-called Asano Butai unit, called after the commander of the half-civilian, half-military unit, Major-General Asano Takoshi. After Japan's capitulation this unit was called the South Sumatra Fuel Depot Unit, and it continued in operation till October 1, 1946, for the following purposes only:

1. To distribute oil products to Allied, Japanese and Indonesian authorities;
2. To continue operating the electric power plant, the water works, telephone, etc.;
3. To attend to a little maintenance work in the refineries and living quarters attached to the refineries.

On October 1, 1946, the refineries at Pladjoe and Soengei Gerong were handed over officially to the oil companies. The entire personnel of the Asano Butai unit were soon evacuated, except for a small number who were kept in Palembang to give information about the activities during the Japanese occupation.

The first Dutch troops landed at Palembang on October 28, 1946.

In Java and Sumatra conditions have made progress very much slower than in Borneo.

The Royal Dutch-Shell's fields at Pladjoe (Sumatra) are now producing 108,000 tons a month, and the refinery at Pladjoe, having now reached its pre-war capacity of 200,000 tons monthly, is again processing imported crude oil. (Standard-Vacuum's refinery near Pladjoe has also resumed operations). The Sourabaya area (Java) is now producing 5000 tons of crude oil a month, which is treated at Wonokromo refinery.

The Group's oilfields and plants in Middle and Southern Sumatra and in Central Java still remain inaccessible for the normal resumption of work.

When the agreement of Linggadjati was initialled it was hoped that the various properties would be handed back to the oil companies. Since then, however, differences of interpretation have prevented the implementation of the agreement, and the situation is quite indefinite. It is believed that some of the fields in Sumatra and Java are being worked in primitive fashion by the Indonesians and some oil is being processed. At Tjepoe, for example, the Indonesians are using 23,000 coolies in the refinery where before the war 3000 were employed. Information on all these properties is very scarce but it is known that Pangkalan Brandan refinery was heavily damaged. In both Java and Sumatra a lot of cleaning and repairs have to be done to roads, bridges, houses, etc., in addition to work on the oil installations themselves.

The above may have given some indication of the problems involved in reconstructing the oil facilities in the East Indies. According to preliminary estimates a total of about 2,000,000 tons of equipment, machinery and materials will have to be procured. An additional difficulty hampering reconstruction in the Netherlands East Indies is that not only has part of the well-trained native staff died or been killed or deported by the Japanese, but also, of the pre-war European staff, numbering some 1500, about one fifth were killed in action, or died during, or as a result of, internment, while the remainder have needed a long holiday to recover from their terrible experiences during the Japanese occupation.

The examination of metals and metal structures up to 9 inches thick for all types of internal flaws is a new service offered by Gamma Rays Ltd of Foundry Lane, Smethwick, Staffs.

Anglo-Iranian Oil Co. production of crude oil in Iran during September 1947 was 1,577,000 tons and during October 1,687,000 tons, making a total for the first ten months of 1947 of 16,629,000 tons.

COUNCIL COMMENTARY

COUNCIL met on December 10 and, after the formal passing of minutes, proceeded to discuss several matters arising from them. It was decided to keep the Engineering Committee in being as an advisory body rather than one expected to initiate items for discussion by Council.

Some uncertainty being unavoidable about the date of the Presidential address, it was decided to leave the matter in the hands of Professor Garner and the Hon. Secretary, it being desirable, if possible, to have this address coincide with the Annual General Meeting.

A cable of congratulations, which had been sent by the Institute to Professor Ipatieff on the occasion of his eightieth birthday, elicited a warmly appreciative letter from Dr Egloff, which was read to Council.

The Hon. Secretary reported that letters had been sent to all retiring vice-presidents and council members, drawing their attention to the new election procedure under the revised by-laws. Council accepted the ballot paper format recommended by an *ad hoc* committee, which had studied the matter, and the accepted form will be used for the forthcoming elections. An attempt is made to give as much relevant information as possible about candidates for the guidance of electors.

Among other matters discussed were nomination papers, Council Commentary, finance, education, the brochure, a report from the Parliamentary and Scientific Committee and correspondence. Finance could not yet be discussed in detail but, in general, possible and desirable measures to arrive at a healthier state of affairs were outlined.

The Education Committee tabled a report dealing with the new City and Guilds examinations, the passing of which would entail a sound knowledge of petroleum technology. It was stated that the Northern Education Authorities were not yet aware of these developments and Mr Thornton was asked to arrange wide dissemination of information (concerning these matters), both in educational institutes and throughout the industry. To derive full benefits, it will be necessary to have active co-operation between the industry and educational institutes, including encouragement of youths willing to study and qualify along this route to Associate Fellowship of the Institute.

Professor Garner was confirmed as deputy chairman of the Education Committee.

It was reported from the Parliamentary and Scientific Committee that difficulties in obtaining scientific books had been experienced as a result of import restrictions. Members were asked to notify the Secretary if such difficulties did arise, although no one present had in fact met this particular trouble.

In a letter, Mr R. I. Lewis tendered his resignation from Council in anticipation of his retirement from the industry, but was asked to remain on Council until the end of the Council year. Dr F. Morton was appointed Chairman of the Research Committee, which was asked to nominate a Deputy Chairman.

Col. Auld agreed to pass to Public Relations Committee a summary of his report on the Glasgow Engineering Centre.

Finally, it was agreed to send advance copies of the Institute brochure to the Branches for effective use by Branch Secretaries in their continued endeavour to help the drive for new members, particularly among non-technical grades.

LUBRICANTS UP TO DATE

By E. A. EVANS (President-Designate)

A MEETING of the Scottish Branch of the Institute was held in Edinburgh on December 12, 1947, the chair being taken by Mr Robert Crichton. An audience of about 100 were present, and Mr E. A. Evans, president-designate of the Institute, delivered an address on "Lubricants Up To Date," a summary of which follows.

The development and application of chemical additives for lubricating oils is a remarkable story of forces of circumstance, vision and application. It is difficult to see how certain phases of engineering could have developed in the way they have without them. Certainly development in the future must be greatly influenced by their availability. Additives were introduced to improve the highest class of lubricants, and definitely not to bolster the lower grades. The original types were devised to give oils a longer life by bestowing upon them an even greater resistance to oxidation than could be achieved by the best known methods of refining. In 1924 the two principal oils which needed such protection were those used in electrical transformers and steam turbines installed in electric power stations. Like most inventions the idea was but slowly accepted. But in 1927 an engineering development occurred which compelled a departure from orthodox lubrication to take place. This was the introduction of the hypoid gear for the back axle of motor cars. The Packard Company of the U.S.A. was quick to realize its possibilities. But, unfortunately, no known oil would lubricate it satisfactorily. So research was started, and ended with a new type of lubricant, which became known as the extreme pressure lubricant. Since then extreme pressure lubricants have permitted engineers in many branches to increase the loads upon moving parts without fear of failure.

In a motor vehicle engine oxygen is the prime requirement of an oil to lubricate, and yet it is its worst enemy. All the carbon, sludge, and acid which forms in the engine can be traced back to oxygen. How to maintain oxygen activity and how to restrain its destructive proclivity at high temperatures was the problem facing the chemist. He produced a new type of anti-oxidant which increased the time between top-overhauls of engines. High speed diesel engines working in hot climates intensified the problem by producing stuck piston rings in profusion.

Probably the greatest development in the production of additives in internal combustion engines has been for the diesel engine, because the problem is much more acute in them. It must not be assumed, however, that research has been exclusive to the diesel engine, because a great deal of concentrated thought has been given to the petrol engine.

The use of additives for the internal combustion engine was extensively practised in the Service vehicles during the war. Admittedly, one type of lubricant was used for all internal combustion engines as a matter of convenience in distribution. Now that the war is over a more detailed consideration is being given to the respective needs of diesel and petrol engines. The immediate needs are to keep the engine cleaner for a longer period, but the use of additives in the future will be to enable the engine designer to get more power out of the engine without increasing its size. This is of enormous importance.

The address was followed by a discussion, and the meeting terminated with votes of thanks to the lecturer (proposed by Mr J. M. Caldwell), and to the chairman (proposed by Mr David Caldwell).

PERSONAL NOTES

Our congratulations to *Sir Frank Smith*, G.C.B., C.B.E., F.R.S., F.Inst.Pet., on his being awarded the U.S. Medal of Freedom with Silver Palm for "exceptionally meritorious service in the field of scientific research and development" during the war.

To *Sir Frederick Godber*, F.Inst.Pet., our congratulations on his having had conferred upon him the honour of Grand Officer in the Netherlands Order of Oranje-Nassau. This well-merited award was made in recognition of his services to the Netherlands during the war and post-war periods.

H. Dobson, A.M.Inst.Pet., recently retired from the Anglo-Iranian Oil Co. after 18 years service in Abadan.

C. T. Brunner, F.Inst.Pet., *C. H. S. Haygarth*, F.Inst.Pet., and *A. Hyman*, have recently been appointed assistant general managers of Shell-Mex & B.P. Ltd.

R. E. F.-S. Bampton, A.M.I.Mech.E., A.M.Inst.Pet., has left UNRRA and has joined the North German Oil Control as senior control officer.

It is with pleasure that we record that in 1940 *Lt.-Col. R. W. Marshall*, R.A.S.C., M.Inst.Pet., was Mentioned in Despatches and was, in 1943, awarded the O.B.E. for services in the field.

R. O. Young, B.Sc., A.R.S.M., A.M.Inst.Pet., has recently left Trinidad Leaseholds Ltd., and has joined the North Venezuelan Petroleum Co. Ltd.

Ionel I. Gardescu, M.Am.Assoc.Pet. Geol., M.Inst.Pet., who was formerly with The Texas Co., is now petroleum engineer and geologist with Ralph E. Davis Inc.

R. I. Watson resigned his position as a director of Anglo-Iranian Oil Co. Ltd. from December 31, 1947, and *E. H. O. Elkington* was appointed a director as from January 1, 1948.

Lt.-Col. E. C. Masterson, B.Sc., F.Inst.Pet., has recently resigned from the general management of "Unirea" S.A. Romana de Petrol, the Roumanian subsidiary of Phoenix Oil and Transport Co. Ltd., and has joined the head office of Kuwait Oil Co. Ltd. He first joined "Unirea" in 1920 and became its general manager in 1935. In 1940 he joined the British Army in Egypt, was appointed head of the Oil Section of the British Military Mission to Roumania in 1944, and in 1946 was released in order to rejoin "Unirea." Unfortunately he was unable to obtain a re-entry permit into Roumania.

L. A. Pym, A.M.Inst.Pet., has been appointed to succeed *C. Saunders* as general manager of Australasian Petroleum Co. Pty. Ltd., who has been appointed London manager of Middle East Pipelines Ltd.

Eric N. Avery has been appointed general manager of Shell Co. of Australia Ltd. in succession to *R. G. Hopkins* who has taken up a position in London.

OIL MEN IN THE HONOURS LIST

The following are included in the New Year Honours List and to them we offer our congratulations:

Knight Bachelor

Harry Ralph Ricardo, chairman and technical director, Ricardo & Co. Ltd.

C.B.E.

Archibald Wilfred Lawson, O.B.E., chief operating officer, Petroleum Board.

Conrad Powell-Johnstone, manager, Burmah-Shell Oil Storage & Distributing Co. of India.

Percy George Graham Salkeld, M.B.E., general manager, Steel Brothers & Co. Ltd., Burma.

O.B.E.

George Nigel Stafford Gobey, assistant general manager of administration, Anglo-Iranian Oil Co. Ltd., Teheran.

Alan Warwick Percy, branch manager, Burmah-Shell Oil Storage & Distributing Co. of India, Bombay.

PETROLEUM IN PARLIAMENT

Tankers

The Parliamentary Secretary to the Ministry of Transport stated on December 8 that the total freight paid by Britain for American oil tankers in 1946 was approximately $42 million, and that the estimate for 1947 was $30 million.

The total tonnage of tankers of 1600 gross tons and over on the U.K. and Colonial register at September 3, 1939, was 3·007 million gross tons, including about 60,000 gross tons of unserviceable vessels. The total tonnage at October 31, 1945, was 2·616 million gross tons including 100,000 unserviceable. Eleven tankers were acquired from the U.S. in 1946 and 40 in 1947, the total cost of these 51 ships being about $92 million. It was uncertain whether any more American tankers would be available for purchase by other than U.S. citizens.

Launchings of new tanker tonnage in U.K. yards for British owners were:

Year	Number	1000 gross tons	Year	Number	1000 gross tons
1935	8	51	1938	31	231
1936	20	149	1939	16	143
1937	19	145	1946	42	299

The expected figure for 1947 for British owners was 19 ships totalling 140,000 gross tons and the estimate for 1948 was 17 ships with a total of 200,000 gross tons.

Motor Spirit from Iran

On December 18 the Minister of Fuel & Power intimated that he was satisfied that no agreement entered into by the Anglo-Iranian Oil Co., in which H.M. Government hold a large interest, with the American Arabian Oil Co. or other companies militates against the availability of petrol from Abadan for consumption in the sterling area nor adversely affects the price paid by the sterling area for its normal requirements.

Motor Spirit Production

About two million tons of motor spirit was produced in the sterling area, including that produced by the Anglo-Iranian Oil Co. at Abadan, in the first nine months of 1947. This statement was made by the Parliamentary Secretary to the Ministry of Fuel & Power on December 11.

Agricultural Supplies

The Minister of Agriculture said on December 18 that in the first nine months of 1947 his department obtained approximately 15½ million gallons of fuel oil and approximately 760,000 gallons of lubricating oil.

B.S.I. SPECIFICATIONS

New in revised specifications recently issued by the British Standards Institution are:

B.S. 209:1947. Fuels for Oil Engines. This revision of the 1937 edition has changed the title from that previously used and also permits the incorporation in the fuel of ignition-promoting or other additives. The methods of test have also been amended to conform to up-to-date practice. Price is 7*s.* 6*d.* post free.

B.S. 1418 : 1947. Mastic Asphalt Damp-proof Courses and Tanking. This standard is one of a series for mastic asphalt for building purposes. The material is specified by composition and some recommendations relating to the laying of the material are given. Price is 2*s.* post free.

Draft Standards. Drafts recently circulated for comment include CJ.1759, flanged steel outside-screw-and-yoke wedge gate valves for the petroleum industry. Copies are available to non-members of the B.S.I., price 2*s.* post free.

PROPOSED LONDON BRANCH

In London those interested in petroleum have been provided with an interesting programme of papers by the Institute of Petroleum. It has been apparent for some time, however, that there exists in the Institute a number of people for whom the Institute meetings are of but casual value. The preponderance of highly technical papers, of necessity, limited the appeal of the meetings and left a large body of those interested in general and less technical aspects of our industry without a proper medium for expression or for the opportunity of discussion. In the provinces this is provided by the branches.

To fill this gap, Council is being asked to give its approval to the formation of a London Branch which, it is hoped, will bring together those for whom the outlook at Institute meetings is too specialized. The type of programme is intended to interest a wide section of those engaged in the petroleum industry, whether technically inclined or not. It will also be designed to attract members of other industries, and in particular, those industries which utilize petroleum products.

The urge for such a medium of expression was felt initially by the younger members of the industry and it is the hope of those sponsoring the proposed branch that they, together with representatives from as many sections as possible of petroleum-minded people, will share in determining the course of the proposed venture.

The character of the branch will lend itself to informality and it is intended that its meetings shall preserve an atmosphere conducive to free-and-easy discussion, which will tempt the most timid to feel at ease and to participate actively at the gatherings. Nor is it intended to neglect its social life. Meetings, discussions, debates, brains trusts, etc., will all contribute to the programme, as in no less measure will visits to installations and other works of interest.

Membership will be open to corporate members of the Institute who express a wish to join, to Student Members and to others engaged in the petroleum and allied industries, and to those interested in the use of petroleum products.

It is hoped to inaugurate the branch early in 1948 at the Institute offices in Portland Place, subject to prior approval by Council of the proposal. It is our intention to publicize the new branch as widely as possible but it may be that it will not reach all who may be interested. All who wish for information of the London Branch, and particularly of its inaugural meeting, should write to: N. E. F. Hitchcock, "Stifford Cottage," High Street, Cranford, Middlesex.

VAPORIZATION IN FURNACE TUBES

On February 23 at Manson House, 26 Portland Place, London, W.1, the Institute of Petroleum and the Institution of Chemical Engineers are holding a joint meeting to hear and discuss a paper on the above subject by Mr G. Baars. The meeting will start at 5.30 p.m., tea and light refreshments being served from 5 p.m.

SAFETY RULES FOR CHEMICAL WORKS

The Association of British Chemical Manufacturers has just issued the third edition of Part I of its "Safety Rules for Use in Chemical Works." Since the publication of the last edition in 1938 there have been far-reaching advances in chemical technology and the rules have been revised and extended to incorporate changes in legislation since that time. Copies of this publication are obtainable from the A.B.C.M. at 166 Piccadilly, London, W.1, the price being 7*s.* 6*d.* post free, and *payable with order*.

ACETYLENE PRODUCTION IN GERMANY

By R. B. RANDALL*

THE shortage of petroleum products, more especially of short chain hydrocarbons from the cracking of petroleum, and of carbohydrate material for alcohol production, led to an abnormal importance being attached to acetylene in German chemical industry and research. With cheap power from ample brown coal deposits, this important raw material was substantially supplied via calcium carbide, although other interesting processes of production from hydrocarbons were also in use or in course of development. The purpose of this paper is to outline the more important of these processes, the information being based on the reports of technical teams that have visited Germany since March 1945.

CALCIUM CARBIDE PROCESS

The German carbide and cyanamide industries have been long established, the first industrial plants dating from 1908. But the development of new processes based on acetylene, of paramount importance in the manufacture of artificial rubbers, plastics, resins and solvents, had led to notable increases in both the size of the carbide furnaces and the total production of carbide. Whereas before the war the German carbide production (about 1,000,000 tons in 1936) was more or less equally divided between welding, cyanamide production and acetylene chemistry, the amount used during the war for acetylene chemistry rose to some 55 per cent of an increased output (110,000 tons† a month in 1942[1]). Production of carbide reached a maximum in July 1943 of 141,522 tons a month in Germany and the occupied territories, thereafter declining until it fell to 74,000 tons a month in December 1944.

As an example of German carbide plant mention may be made of the largest single plant in Germany, that of I.G. Farbenindustrie A.G. for Sticksstoff-Duenger at Knapsack,[2] with a productive capacity of 25,000 tons a months. The carbide was produced in eleven furnaces, seven of the old type (built before 1931) and four of the new type (1931–1938).

	Old Type	*New Type*
Power input, kW ..	10,000	23,000
Carbide output, tons/24 hrs.	60–70	150
Power factor (3-phase, 50 cycles), per cent	86	92
Power consumption, kWh/kg carbide ..	4.4	3.2

Söderberg continuous electrodes were used[2b]. At Ludwigshafen[3] the gas evolved from the furnaces (approximately CO 57%, H_2 16%, CO_2 4%, & N_2 23%) was recovered, although this does not appear to have been a general practice.

The carbide industry in Germany is said[4] to contain no radical departure from standard practice, although some details, as, for instance, the special methods of cooling carbide employed at Ludwigshafen[3a], merit attention.

PYROLYTIC PROCESSES

In addition to the normal production via carbide, extensive investigations were made on the production of acetylene by the high temperature pyrolysis of hydrocarbon gases, particularly methane. The methods investigated were (1) the arc process, (2) the partial oxidation

* Fuel Research Station, Department of Scientific and Industrial Research.

† Owing to the difficulty of estimating the production of factories in the Russian Zone, e.g., at Piesteritz, these figures must be treated with reserve.

process, and (3) the thermal cracking process. Of these, only the first reached production scale, although large scale plants were under consideration for both the others.

Acetylene was first produced from the pyrolysis of hydrocarbon gases by Berthelot in 1862, and many investigators have since extended the work. Generally, the acetylene yield per pass has been low: thus the cost of separating or concentrating the acetylene is an appreciable proportion of the cost of production. However, where diluted acetylene can be used, as in the acetone synthesis, these processes may have considerable advantages.

ARC PROCESS

The first, and probably the only, successful large scale production in Germany of acetylene by electrothermal cracking of hydrocarbons was that at the Chemische Werke Hüls A.G.[5]

The plant was designed to run primarily on gas from the Scholven hydrogenation plant (containing approximately CH_4, 70 per cent; C_2H_6, 25 per cent; and C_3H_8, 5 per cent); when bombing cut this off, natural gas from Bentheim (CH_4, 92 per cent; H_2S+CO_2, 3 per cent; H_2, 5 per cent), after removal of the H_2S, was used.

Each arc reactor (Fig. 1) consisted of an earthed water-cooled iron tube, about 1 metre high and 90 mm diameter, having a copper electrode at the top and a water stream injected at the lower end. The feed gas at 1.5 atmospheres pressure was introduced at the top, where vanes imparted a rapid swirling motion to it. The input was at the rate of 2800 cu.m. an hour, of which 50 per cent was natural gas and 50 per cent recycle gas. For each pair of arc reactors (only one of which was run at a time) there was one mercury arc rectifier system fed with A.C. at 6,000 volts, 50 cycle, three-phase, and delivering 1000 amps. D.C. at 7000 volts to the reactor. The reactor tubes had a life of 150 to 250 hours, and were readily replaced, while the life of the copper electrode was 2000 hours. In the arc a temperature of 1600 to 2000 C was reached, and to this the feed gas was subjected for about 1/100 second before being reduced to 150 to 200° by water quench. The process was controlled by increasing the gas flow, at a set voltage and current, until the power factor was 0.7 to 0.75, extending the arc flame to the full length of the arc tube. The electrical energy efficiency in the reactor, that is, the heat supplied in the form of electrical energy compared with the heat required by the chemical reaction, is stated to be between 40 and 50 per cent.

The exit gas (4200 cu.m. an hour), freed from carbon black, had approximately the following composition when natural gas was used as feed:

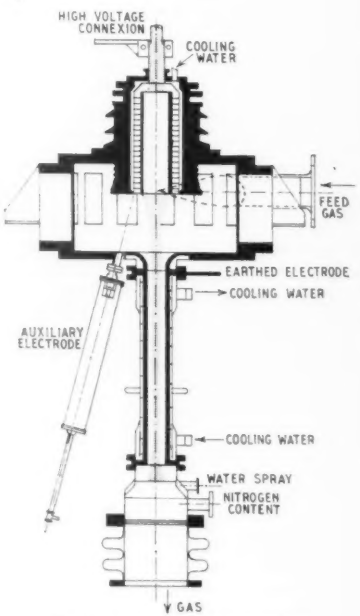


Fig. 1.—Electric arc for acetylene manufacture.[5b]

	Per cent
C_2H_2	13
H_2	52
C_2H_4	1
Saturated hydrocarbons (mainly CH_4)	25
CO	2
N_2	7

Using refinery tail gas the acetylene and hydrogen yields were said to be much higher, and the saturated hydrocarbon yields lower.

After removal of the water and carbon black in cyclone separators followed by passage through filter towers, the exit gas was washed with tar oil to remove aromatics and polymers, and the hydrogen sulphide was removed in luxmasse purifiers. The gas was then compressed to 18 atmospheres and the acetylene dissolved in water. The tail gases were passed to a Linde plant to recover hydrogen and ethylene, and the remainder recycled. The aqueous acetylene solution was reduced in pressure in four stages, finally subjected to a vacuum, and a gas containing 97 to 98 per cent acetylene was obtained from the last three stages. Gas from the first stage of the let down (at 1.5 atmospheres pressure) contained 50 per cent acetylene and was recycled to the compressors.

The total production capacity was 200 tons a day of 97 per cent acetylene, the overall power consumption 12.3 kWh/kg pure acetylene, a figure which is similar to that from the carbide route. 100 kg hydrogenation by-product gas yielded 45 kg acetylene, 9.2 kg ethylene, 5 kg carbon black (disposed of mainly to the rubber industry), and 142.5 cu.m. (approximately 12.5 kg) of hydrogen, the remainder, mainly methane and homologues, being recycled. A plant producing 6.3 tons of acetylene an hour required 160 men a shift, excluding maintenance.

PARTIAL OXIDATION PROCESS

This process (Fig. 2) was developed at the Ludwigshafen-Oppau works of I.G. Farbenindustrie A.G.[6] and represents one of the newest German developments in the production of acetylene. The process circumvents many of the difficult heat exchange problems of the other pyrolytic processes and provides, as a co-product, synthesis gas. The pilot plant was said to have operated successfully for two years.

This process requires substantially 100 per cent hydrocarbon gas and pure oxygen, the heat required for pyrolysis being provided by the combustion of part of the raw material. There were, at Oppau, five units, each burning 800 cu.m. of methane and 400 to 450 cu.m. of oxygen an hour. The methane and oxygen were preheated separately to 500 C before introduction into the reaction vessel, where they were intimately mixed before passing down to the firebrick burner. In the combustion zone, which was 10 cm long and 60 cm diameter, the thoroughly mixed gases attained a temperature of 1400 to 1500 C at approximately atmospheric pressure; the gas velocity through this zone was 8.5 m a second, well in excess of the flame propagation rate for the mixture. Immediately below the combustion zone water spray injectors cooled the reacted gases to 80 to 90 C, after which they were passed through a coke filter to remove soot and tar. Carbon recovered from this process was of too poor a quality to be of any commercial value. The exit gas had the following composition:

	per cent
C_2H_2	8–9
H_2	56
CH_4	6–7
CO	24–26
CO_2	3–4

This dilute acetylene was used directly for acetone synthesis or, if concentrated acetylene was required, compressed to 18 atmospheres and subjected to a water wash similar to that used in the arc process. The final product contained

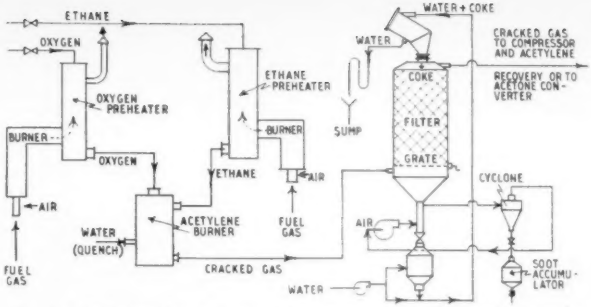


Fig. 2.—KW plant for production of acetylene from ethane and oxygen.[6a]

approximately 70 per cent acetylene and 30 per cent carbon dioxide. Residual gas from the washers was partially combusted with a little oxygen (to oxidize the methane) to give synthesis gas.

Carbon deposited on the underside of the burners was removed once a day by manually operated scraper, and the burners had a life of from four to six weeks. The plant was controlled by the amount of oxygen admitted; excessive oxygen led to low acetylene yields, too little oxygen to a fall in reaction temperature and an increase of oxygen in the exit gas.

A problem which was not satisfactorily solved arose from the occurrence in the reaction vessel of non-explosive pre-ignition of the gas mixture, with consequent high temperatures and destruction of the burners. This phenomenon was greatly accelerated by the presence of iron dust, in spite of the fact that the whole of the inlet side was either of firebrick or sicromal; it was checked when it occurred by reducing the oxygen supply. Pre-ignition was also accentuated by the presence of hydrogen, carbon monoxide, ethylene and other unsaturated hydrocarbons in the methane.

It was proposed to erect a plant to produce one ton an hour of acetylene from ethane, together with 10,000 cu.m. an hour of synthesis gas, at Heydebreck. The following extracts taken from the estimates for that plant, are of interest:[6a]

Ethane, cu.m hr.	3070
Oxygen (including 349 cu.m. for secondary treatment of the synthesis gas), cu.m hr.	3479
Power (120 kW for synthesis, 1900 kW for acetylene concentration), kW	2020
Water, cu.m hr.	520

THERMAL CRACKING PROCESS

The thermal cracking process was developed by Ruhrchemie A.G., in the period 1929–38. A pilot plant was erected at Holten[7] (and later largely destroyed by bombing), and industrial scale plant was designed in 1943 for the Hungarian firm of Nitrochemie A.G., but not erected. The process was based on work by F. Fischer and his collaborators at the Kaiser Wilhelm Institut on the pyrolysis of methane, primarily for the production of benzene. It had been found that the optimum heating period decreased with rising temperature, and that diminished pressure favoured acetylene formation. Best yields were obtained from methane at 1400 to 1500° and 76 mm mercury pressure. No catalyst was required, but the film of hard carbon which formed improved the yield by inhibiting secondary reactions. In developing the process to the larger scale it was necessary (1) to

find a suitable method of maintaining the reaction temperature, the reaction being endothermic, (2) to minimize undesirable by-products, notably diacetylene and carbon, and (3) to concentrate the acetylene to a high degree of purity.

The pilot plant was erected in 1936. It consisted of a regenerative checker brick oven, 4 metres high and 30 cm internal diameter, packed with special refractory bricks. Operation was intermittent; the oven was heated for a period of one minute, during which methane and air passing upwards were burnt, followed by a one minute cracking period in which methane at reduced pressure flowed downwards. Cracking occurred mainly in the top one metre of the oven, which was packed with special alumina tiles which were very costly, although a much cheaper tile was said to have been developed. A temperature of 1500 to 1600 C was attained, and with a throughput of 50 cu.m of methane an hour the contact time was about 1 100 second. The exit gas from the cracking period was shock-cooled to 40° C with a direct water quench. During the cracking period about 75 per cent of the methane was decomposed, half to acetylene and half to carbon, most of the latter being burnt off during the heating period and supplying half the total energy.

The exit gas, which was stated to contain no suspended carbon, had the following composition:

	per cent
C_2H_2	9.8
H_2	70.7
CH_4	15.7
Diacetylene	0.3
N_2	3.5

It was compressed to 10 atmospheres and washed with water to remove the more soluble diacetylene, and the acetylene was then separated by a system of water washing somewhat similar to that used in the arc process.

The following estimates of power and materials were made for the Nitrochemie AG. plant[7b], to produce 7000 kg acetaldehyde* a day from natural gas containing 99 per cent methane:

Acetylene produced	166 cu.m. per hour (4.68 tons/day)	
Total electric power	1077	kW (approx. 3.7 kWh/kg C_2H_2)
Natural gas for reaction	1040	cu. m. per hour
Natural gas for heating	294	" "
Water	100	" "
Steam	0.3 tons.	

REFERENCES

The reports listed below form only a selection of the more important ones from the large number dealing with this subject:

1. Hasche, H. L., *Chem. Eng. News*, 1945, **23**, 1840; C.I.O.S. XXVII—52.
2. (*a*) C.I.O.S. XXVI—54; (*b*) C.I.O.S. XXVII—83.
3. (*a*) F.I.A.T. 859; (*b*) C.I.O.S. XXII—7;
4. C.I.O.S. XXVII—92.
5. (*a*) C.I.O.S. XXXI—75; (*b*) C.I.O.S. XXII—1 & 21; C.I.O.S. XXX—83.
6. (*a*) C.I.O.S. XXX—103; B.I.O.S. 877.
7. (*a*) B.I.O.S. 747; (*b*) B.I.O.S. 1038.

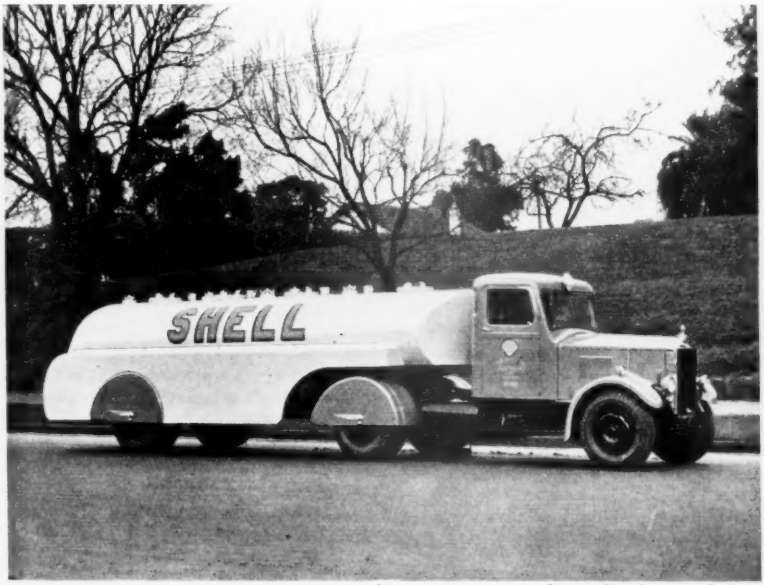
In celebration of its centenary the **Koninklijk Instituut van Ingenieurs** (Royal Dutch Institute of Engineers) has issued a special volume, the petroleum section of which contains articles on Crude Petroleum, by A. W. J. Mayer; The World Reserves of Crude Petroleum, by L. W. Leyds; Some Physical and Chemical Aspects of the Technique of Crude Oil Production and the Influence Thereof on the Organization of Exploitation Services, by J. H. M. A. Thomeer; Modern Views on the Production of Crude Petroleum, by W. R. van Wijk; Catalytic Processes, by P. van 't Spijker and J. van der Burg; Petroleum as Raw Material for the Chemical Industry, by J. Overhoff; Fuels and Lubricants, by J. A. Peletier and A. W. J. Mayer; Asphaltic Bitumen, by F. W. Lutter.

* Reported as 7000 kg acetylene in B.I.O.S. 1038: correction communicated by the author.

Courtesy Anglo-American Oil Co. Ltd.

THEN AND NOW

The three-horse power road tanker above was often seen on British roads in the early years of the present century. Its counterpart to-day follows the lines of the Australian 2000-gallon, 4-compartment, semi-streamlined tanker seen below.



Courtesy Shell Petroleum Co. Ltd.

LUBRICATING OIL ADDITIVES

By A. J. HAM,* (Member)

THE need for additives in engine lubricants arose as a result of the development of engines to operate under increasingly severe conditions of service; certain of the consequent changes in design threw additional burdens on the oil, e.g., bearing corrosion was not a serious problem until the introduction of copper, lead, and cadmium alloys to enhance the load-carrying capacity of bearings. In addition to the ability to reduce friction and wear, lubricating oils for use under these severe operating conditions must possess resistance to oxidation at relatively high temperatures, anti-corrosive action, and the capacity to prevent deposit formation. It becomes necessary to impart properties to the oil which cannot be given by any refining treatment, and for this purpose additives must be used. The main applications of additive type oils have been for heavy duty diesel and aircraft operation. In the latter connexion, it has been argued that at high altitudes the efficiency of aero engines would be increased appreciably by operating at increased temperatures.[1] This would necessitate an improved oil with respect to anti-ring sticking and anti-wear action. New engine designs can be developed using the advantages of such improved oils. This aspect, which has led to considerable co-operation between engine manufacturers and oil refiners, emphasizes that the use of additives is not a temporary expedient to enable engines of current design to function satisfactorily until more suitable straight oils can be produced.

Although activity in the field of additive oils can be said to have started about 1930, very many patents have now been granted. A study of these patents reveals certain general trends, e.g., the increasing introduction of sulphur compounds as anti-oxidants, whereas amines feature less prominently than they did formerly.

REFINING

The two components of a blend, oil and additive, are both of importance and cannot be treated separately; indiscriminate mixing of oil and additives has a very poor chance of producing satisfactory results. In the case of very wide differences in composition, oils will not, in general, respond similarly to a given additive, although it is true that in a series of closely related base oils, minor changes in the concentration of one given additive will produce optimum performance in any of the stocks. Present refining methods were primarily devised to improve oil with respect to its use as a lubricant, employing no additive. Much has been written as to the necessity of compromising in refining, by solvent extraction or acid treatment,[2,3] as over-refining leads to reduced oxidation stability and other undesirable changes. Straight mineral oils prepared with nicely balanced properties may not be the most suitable for use with additives; susceptibility of the oil to the specific action of the addition agent is most important, and for improved "dope response" it is often necessary to over-refine an oil, considered on its own merits. The all-important point is the production of a blended oil with as many of the properties of a perfect lubricant as possible.

With regard to production cost, a balance has to be struck between using the normally refined oil with a large percentage of additive, and an over-refined oil with a smaller percentage of

* Thornton Research Centre, "Shell" Refining & Marketing Co. Ltd.

additive. In either case it is probable that additive types of oil will be retailed at prices slightly above those of straight oils—experience has already shown that improved performance will offset this disadvantage.

SPECIFICATIONS

Specifications for additive oils consist at present of the conventional type; it is not uncommon for one such specification to be met by a number of oils differing considerably in those chemical or physical properties which contribute directly to their behaviour in service. Engine troubles which have occasioned the widespread introduction of additives, e.g., ring sticking, lacquer decomposition, sludge formation, and excessive corrosion, occur in engines where oil deterioration is complicated by the influence of the combustion process, and by the presence of materials promoting oxidation. This implies that, until factors contributing to engine troubles are more thoroughly understood, the only satisfactory test of an oil is its performance in the service for which it has been designed.

The disadvantages of such engine tests used as specifications are that, apart from their expense, they can merely correlate with certain commercial engines in current production, even when well-standardized and precisely carried out; many factors operate simultaneously, and discrimination is not always good. The use of engine tests in oil specifications, a practice widely employed during the war by the U.S. Army and Navy, is in itself an admission that the factors which test the suitability of the oil, i.e., those critical conditions to which the oil is exposed in the engine, have not been elucidated and defined. Until this has been done, laboratory tests cannot be designed to parallel engine conditions, and hence adequate specifications of the requisite chemical and physical properties to ensure satisfactory oil performance in service cannot be laid down. When more is known as to the properties of the oil and the engine conditions which control ring sticking, corrosion, and other engine phenomena, specifications for heavy duty oils can be placed on a more realistic basis.

GENERAL PROPERTIES

Apart from a profound effect on one or two specific aspects of the behaviour of the base oil, there are several properties which it is convenient for any additive to possess. Surprisingly few of these desirable properties are absolutely necessary, but by considering them it may be profitable to approach the subject in a rather different manner from that usually adopted, i.e., the discussion of additives in classes, each having a specific function.[3, 4]

(1) *Solubility in Oil.* This property would appear at first sight to be an inevitable one and is, in fact, possessed by the large majority of additives; solubility must, in general, be maintained over the considerable temperature range found in engine operation. Not only should ultimate solubility be complete, but solution should take place readily; if this is not so, complicated blending procedures become involved. This in turn may increase plant costs, and also the possibility of decomposing the additive in the process if, for instance, blending necessitates the use of elevated temperatures.

A notable exception is provided by a very effective anti-foaming agent containing silicon, which, while effective at a few parts per million, does not dissolve in oil to any appreciable extent. Again, substances added to an oil in order to increase its viscosity, or to improve its viscosity index, may depend upon limited solubility varying with temperature for their action. Unlike

many additives these substances are frequently hydrocarbon in nature, e.g., *iso*butylene polymers, for which a patent was obtained as early as 1932. Although their mode of action is not thoroughly understood, it is probably related to their existence in the oil as colloidal aggregates. If the nature of the colloidal solution changes with rise in temperature, the polymeric substances may increase viscosity more at elevated than at low temperatures, thus improving viscosity index. The possibility arises of increasing yield and reducing treating cost by incorporating a viscosity index improver in a less severely refined oil. Disadvantages would be encountered, however, such as decreased oxidation stability, poor colour, and lack of susceptibility to other additives.

To return to the question of the solubility of additives in oils; the nature of the oil itself is important, some additives tending to be less soluble in more viscous fractions. It is not profitable, however, to attempt to use an additive too generally, but rather to admit that it gives its best performance in certain specific base oils to which stocks it is to be restricted; thus, solubility in a very wide range of oils may not be required.

Anti-rust additives provide an interesting case where high oil solubility may not be desirable; such solubility can act against the tendency of the additive to concentrate on the metal surfaces with which the oil is in contact, rather than in the bulk oil itself.

Pour point depressors, for instance wax phenols, have the property of causing wax crystals to assume a shape in which they cannot interlock in their usual manner. Waxy oil will flow at lower temperatures when such additives are used; they are not necessarily oil soluble, finely divided solids or colloidal substances being quite effective.

Additives which have very desirable properties but which lack oil solubility, may often be improved in this respect by the chemical addition of constituents conferring oil solubility, i.e., by alkylation. Alternatively another compound, such as a long chain alcohol, may be added with the express purpose of promoting solution or, at least, thorough dispersion of the additive in the oil.

(2) *Insolubility in, and lack of reaction with, aqueous solutions.* As attention is being confined to engine oils, it will be apparent that additives for such oils should dissolve in oil rather than in water. This, together with lack of reaction with aqueous solutions, can be taken as a second general property. Water diluent which finds its way into the crankcase from the combustion chamber would leach out water-soluble additives. Certain chemicals promote the displacement of water by oil at metal surfaces, thus operating against rust formation; clearly this action will be adversely affected by any tendency of the additive to dissolve in the water. While lubricating oil additives are invariably insoluble in water, many are capable of reacting with water to a greater or less extent. When the chemical constitution of various additives is considered, this is by no means surprising; metals attached to aromatic nuclei are frequently present in additives. Hydrolysis to hydroxides, or more probably to sulphates under engine operating conditions with an appreciable amount of sulphur present, can be readily envisaged. In practice, trouble from this source is infrequent; possibly the temperature is too high and the time of contact of additive with water too small to give appreciable hydrolytic action.

(3) *Colour.* The colour of additives and additive type oils is important. Clear oil, highly refined, looks good; whether it is suitable for the service for which it is designed is another matter. Colour can be added or removed at will, and in general has little significance; nevertheless that attitude cannot be maintained when the all-important

question is asked "will the customer buy the oil?"

In point of fact, several successfully developed additives are dark-coloured and do give blends of colours which can only be considered as inferior to those of the original oils. Such additive type blends have been justified by their performance in practice, and—being already dark—do not show the rapid darkening frequently encountered with light-coloured, highly refined oils. Again, tendency to change colour on very prolonged exposure to light may not prevent an oil from being used in totally enclosed equipment. In some cases, however, additives with otherwise desirable properties have had to be rejected because the action of light has produced not only changes in colour, but even the formation of oil-insoluble deposits.

(4) *Volatility*. The volatility of an additive must be low, otherwise when the blended oil is exposed to high temperatures the additive will vaporize preferentially and its concentration be decreased, apart from the action of such vaporizing additive materials in the cylinder above the piston, and in decreasing the flash point of the blend.

(5) *Stability*. An essential property of any additive is the possession of a considerable degree of stability; one aspect of this rather wide subject has already been mentioned, stability with respect to hydrolysis by aqueous solutions. It is also desirable that additives should be stable with respect to thermal decomposition up to 500°F or more, as a small amount of oil will find its way to the cylinder walls and the top of the piston where high temperatures occur.

Certain commercially available additives do not possess the requisite stability and—while improving oil performance in some respects—tend to decompose at elevated temperatures and to aggravate deposit formation, particularly in the combustion chamber. It is interesting to note that several cases are known in which reactions occur, on heating, which by no means detract from the value of the additive. Changes in structure take place to give other oil-soluble products, which are perhaps even more effective than the original additives.

Stability in the sense of chemical inactivity can only be said to be a desirable property with considerable qualifications. Additives designed to prevent seizure of metal parts at extreme pressures and temperatures must possess chemical reactivity under such conditions, with respect to the metallic surfaces to be lubricated. It appears that such compounds containing phosphorus, sulphur, and halogens owe their action to the formation of easily sheared surface layers of metallic phosphides and chlorides, thus preventing local welding and tearing of the metal surfaces. It may be mentioned that such additives must be selected carefully according to the application envisaged; reaction with metallic surfaces may become so increased under abnormal conditions that the additive itself causes excessive corrosive wear, although friction may be much reduced.

Anti-oxidants represent one of the most common of the various classes of additives. In the vast majority of engine troubles which arise in service, oil oxidation plays some part—usually a major rôle; acids corrosive to bearing materials, sludges which causes a generally dirty engine and oil line plugging, gummy deposits promoting ring-sticking, etc., can in many cases be traced to oil oxidation products as their main source. The mode of action of anti-oxidant additives is not always clearly understood; three general effects may be distinguished. Anti-catalysts can retard oil oxidation in that they passivate the surfaces of the metals which would otherwise act as catalysts for oil oxidation—either by promoting reactions at the metal surface, or by dissolving to give oil-soluble catalysts.

Additives which have this effect must be sufficiently reactive to form strongly attached films on the metals; if actual chemical reaction occurs, it does so under much milder conditions than those obtaining in the case of the "extreme-pressure" additives mentioned previously. Examples of such protecting additives, known as "passivators", are again, sulphur-containing compounds. Soluble catalysts may be countered by anti-catalysts of a second type, sometimes termed metal "deactivators", which react in oil solution to form complex compounds with the soluble catalysts; such complexes may or may not be oil soluble, but must not themselves promote oil oxidation. The most common types of compounds in use contain the di-amine group with various alkyl groups attached to the nitrogen atoms. The third manner in which oil oxidation may be retarded relates to effects on the oxidation of the oil itself, in the absence of catalysts. In this class of anti-oxidants, or oxidation inhibitors, the necessity for some degree of instability with respect to oxidation is clearly brought out.

The resistance of various types of hydrocarbons to oxidation varies considerably; paraffins oxidize readily, as do benzene derivatives. Substituted naphthalene derivatives are effective anti-oxidants, but the power of resisting oxidation found in oils cannot be explained on this basis. Stability of oils must be related to the presence of non-hydrocarbon inhibitors of oxidation. The naturally occurring inhibitors in the oil are often present as sulphur-containing compounds; unfortunately these inhibitors frequently promote sludging, and their removal during refining is not to be discouraged.

Highly refined mineral oils oxidize by means of an auto-catalytic mechanism; that is, the initial products of oxidation, almost certainly of a peroxide type, are themselves promoters of further oxidation. The reaction of one oil molecule with oxygen can initiate a series of reactions in the course of which many hundreds or even thousands of individual oil molecules may be oxidized. These so-called "reaction chains" will be broken by any substance which can render the initial products of reaction, of a peroxide type, inactive as regards their further effect on oil oxidation. The most obvious and usual manner in which inhibitors of oil oxidation can be effective, is by showing a greater tendency to react with, that is to be oxidized by, the chain propagating peroxides. Oxidation products of the inhibitor peroxides reaction must, of course, be inert themselves and not influence the oxidation of more oil molecules; such products should not have any other detrimental effects on the oil. It may be noted that oxidation to form deposits, together with corrosive action provide reasons why fatty oils are not widely used in H.D. oils, although they give low coefficients of friction.

Inhibitors of oil oxidation are often aromatic compounds which contain phosphorus, sulphur, and/or amine or phenolic groups, capable of being themselves oxidized. When such compounds have been oxidized, the oil then oxidizes, in a manner which is much the same as that of an uninhibited oil; the additive has merely postponed the onset of auto-catalytic oxidation.

(6) *Compatibility*. Compatibility is, in a general sense, one of the most important of the properties of any additive; the term has been much abused, and in a short space of time various shades of meaning have developed. Two components of an oil blend can be regarded as compatible if they do not give visible evidence of reacting together, for instance, by colour changes or the formation of oil-soluble matter; on the other hand, two such components can be taken as compatible only when their individual properties are strictly additive. This latter definition will be rejected, as it seems illogical

to term "incompatible" two components which mutually enhance each other's good properties.

It was pointed out above that the oil and additive must be suited to each other—and not selected at random; this statement holds good in the case of blends in which a number of additives are present. Now it is not at all uncommon to use two or more additives each with a specific purpose; thus anti-oxidants and anti-wear agents, or detergents and anti-oxidants are frequently mixed together in heavy duty type oils. These various compounds must not impair each other's specific actions—and this "compatibility" has to be maintained through all the troubles and trials of the life of the blend, e.g., various conditions of temperature, moisture content, etc. As in the case of other general properties, there are a number of instances of the successful use of additives which do not possess the desirable property, in this case compatibility.

Mention has been made of the manner in which certain anti-oxidants such as sulphur-containing compounds passivate metal surfaces by forming a protective film on them; also it is clear that anti-corrosion or anti-wear agents, and additives which reduce friction and promote "oiliness", all have their most obvious application at metal surfaces. On the other hand a class of additive of growing importance is that of "detergents", which enhance engine cleanliness. Should a detergent exert a washing action on deposits already formed, then there is the danger that it will run counter to the various classes of additive which owe their effect to the formation of protecting films on metal surfaces; a strongly acting detergent might promote corrosion. Detergents can also be antagonistic to oxidation inhibitors, in that, by maintaining clean surfaces they can render homogeneous or heterogeneous catalysis more probable. Thus, formation of oil insolubles may be accelerated, although they do not form deposits as readily as in the absence of the detergent. If a detergent acts merely in maintaining insoluble material in a state of suspension as very small particles, it will not be incompatible with anti-wear and metal passivating agents. In such a case, however, metal particles active as oxidation catalysts may be kept in suspension and promote overall deterioration. Metal salts of carboxylic acids and phenates are the most common types of detergents; some non-metallic compounds are known, but are less effective especially at higher temperatures.

Another case of incompatibility may be mentioned. Friction and wear are interdependent to some extent, a high coefficient of friction will cause high temperatures and as an ultimate result wear will be increased. However, fatty acids and their derivatives are commonly used to reduce friction, i.e., they promote "oiliness", and under some conditions such additives can actually increase corrosive wear. Anti-wear agents, such as tricresyl phosphate, may be added simultaneously to an oil to counteract this. Both types of additive are effective at metal surfaces, but by different mechanisms, and will compete for position on the metal surface; for this reason the problem of reducing the sum of corrosive and abrasive actions under certain conditions of service is by no means an easy one.

One method of decreasing the troubles which may arise through incompatibility of a number of additives used together in a blend, is the replacement of such a mixture by means of one multi-functional additive. Metal salts of carboxylic acids, containing aromatic rings in which phenolic or amine groups are substituted, can function as detergents and anti-oxidants.[5] Detergent action leading to improvements in engine cleanliness, and decrease in ring-sticking tendency, appears to be conferred by metal carboxylates and phenates. An additional

action of metal phenates consists in some degree of buffering action; that is, they react with the more active acidic substances produced in the oil, thus tending to reduce corrosion. Oil solubility of additives can be promoted by alkylation; anti-oxidant action may be conferred by phenols, amines, phosphites, or sulphur-containing groups; such groupings often have anti-corrosive actions—especially if they act as metal passivators. Phosphate groups may confer anti-wear action, and sulphur, chlorine, and phosphorus-containing groups give E.P. or load-carrying characteristics. Now, attempts to produce these multi-functional additives have been only partially successful; it is often more easy to blend together compounds each with a particular function, than to introduce a number of groups into one molecule while retaining the specific actions of such groups.

Another alternative, in producing a blend with a number of enhanced properties, is to use smaller concentrations of the more effective additives. Thus, if a compound proves to be extremely effective in improving a given property, then it can be used at very low concentrations. This will, of course, be an economic advantage, as well as decreasing the danger of any disadvantageous property, such as incompatibility, becoming serious in the final blend. If a blend already contains two additives, each improving a specific property of the original oil, and it is desired to improve a third property, the new additive must not upset the balanced action of the two originally present.

It can be stated that certain mixtures of additives have arisen because one compound may be so efficient in one respect—detergency for instance—that its use is deemed advisable in spite of, say, increased corrosion. The anti-corrosive agent added is then intended mainly to counteract the increase in corrosion arising from the detergent, as the original oil may have been non-corrosive.

There is one wider aspect of compatibility, that is as between competitive products. It must be obvious that the mixing of two lubricants in service, which are obtained from different manufacturers, may well involve incompatible additives. This was early recognized, and engine manufacturers will now approve oils only after they have been shown to be compatible with other oils previously approved for similar service.

It seems that a rather gloomy picture has been drawn in this consideration of the compatibility of additives. In some ways this was deliberate, in that it was intended to show that, while there are thousands of compounds which can have beneficial effects on some specific properties of an oil, the development of an entirely satisfactory blend is a difficult task.

CONCLUSIONS

Some brief mention of synthetic lubricants is perhaps in order; one large company in the U.S. is marketing a motor oil which is entirely synthetic. There are certain limitations to the variations in properties possible with hydrocarbons, and these entirely synthetic oils are said to combine, for instance, high viscosity indices with much lower pour points than would be possible with any combination of hydrocarbons. This is, of course, still more revolutionary than the use of additive-type lubricants, in which, as has been indicated above, the oil should be considered as an equal partner with the additives. However, in the same way that both straight mineral oils and those containing additives have their own particular applications, so entirely synthetic oils will probably supersede other types in certain fields only; that this must be the case at least for the time being is indicated by the relatively high price of synthetic lubricants.

In conclusion the author wishes to express his thanks to the "Shell" Refining & Marketing Co. for permission to publish this paper.

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(3) Webber, M. W., *Petroleum*, 1945, **8**, 76.
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(5) Reiff, O. M., *Industr. Engng Chem.*, 1941, **33**, 351.

The Petroleum Division of the American Institute of Mining & Metallurgical Engineers has recently inaugurated a **Petroleum Division Certificate of Service.** This is intended as a means for recognizing the gratitude of the society to those individuals who make exceptional contributions in connexion with the economic production of petroleum. The award may be retrospective to March 24, 1922.

The Wellman Smith Owen Engineering Corpn. Ltd. has removed its head office to Parnell House (opposite Victoria Station), London, S.W.1. Telephone numbers remain unchanged as Victoria 7752–3–4, except for the furnace construction department which can be obtained direct at Victoria 9684–5.

An **Electronic Process Timer** which has a wide variety of applications is the subject of a leaflet from Electro Methods Ltd., 220 The Vale, London, N.W.11.

Latest bulletins from the National Supply Corporation are on Type V Swivel (No. 316), Type R–3 Swivel (No. 343), Type F Swivel (No. 344), and Type D Swivel (No. 346). Ratings are 55 tons, 200 tons, 100 tons, and 150 tons respectively.

FORTHCOMING MEETINGS

INSTITUTE MEETINGS

Aerial Photography and Exploration for Oil. Dr Ir. N. G. M. Taverne. At 26 Portland Place, London, W.1, 5 p.m., February 11.

Vaporization in Furnace Tubes. G. Baars. (Joint Meeting with Institution of Chemical Engineers.) At 26 Portland Place, London, W.1, 5 p.m., Monday, February 23.

The Production of Oil from the Fields of South-west Iran. H. S. Gibson. At 26 Portland Place, London, W.1, 5 p.m., March 10.

Properties of Paraffin Wax as an Effect of Composition. S. T. Minchin. At 26 Portland Place, London, W.1, 5 p.m., April 14.

NORTHERN BRANCH

Engineers' Club, Manchester, 6 p.m., February 9.

SCOTTISH BRANCH

Three Decades of Petroleum Refining—A Retrospect. A. E. Dunstan. North British Hotel, Edinburgh, 7.30 p.m., February 27.

MEETINGS OF OTHER SOCIETIES

The Formation of Ethylenic Polymers. Prof. H. W. Melville. The Chemical Society. At the University, Bristol, 5.30 p.m., February 12.

Recent Developments in Combustion. Dr D. T. A. Townend. Society of Chemical Industry and Institute of Fuel, at the University, Bristol, 5.30 p.m., February 19.

Marine Lubricants and Lubrication Practice. G. M. McGavin and H. J. Nicholson. Institute of Marine Engineers (Junior Lecture), at Municipal Technical College, Liverpool, 7 p.m., February 26.

The Trade and Technical Press. R. E. Dangerfield. Royal Society of Arts, London, 2.30 p.m., March 10.

Heat Transfer. A. D. Davidson. Society of Chemical Industry, at Geological Society, London, 5.30 p.m., March 16.

Chemicals from Petroleum. K. Gordon. The Royal Institute of Chemistry (Teesside Sect.), March 18.

Value of Statistics to the Chemical Engineer. N. T. Gridgeman. Institution of Chemical Engineers, at College of Technology, Manchester, 3 p.m., March 20.

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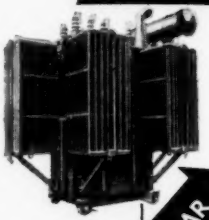

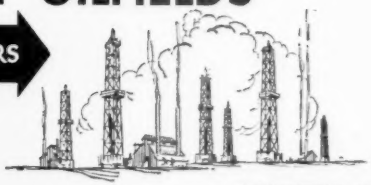

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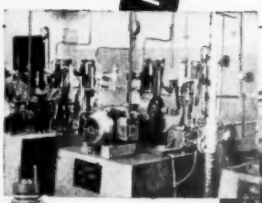

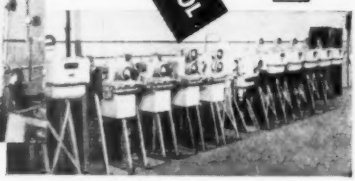

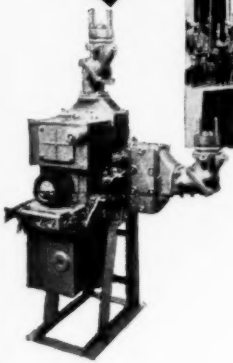

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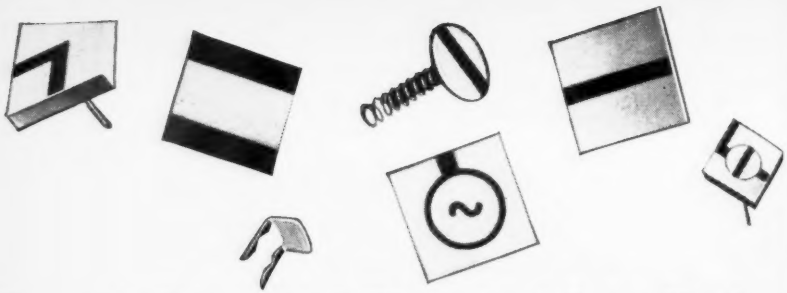

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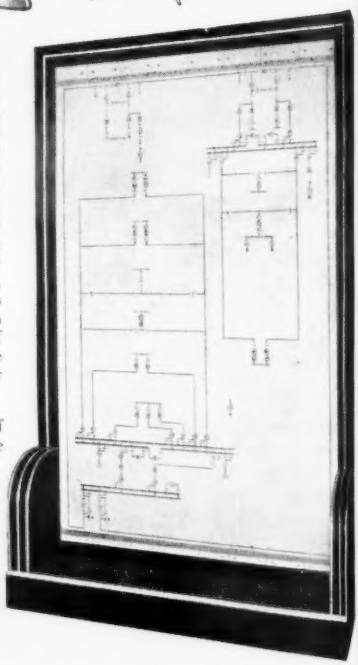

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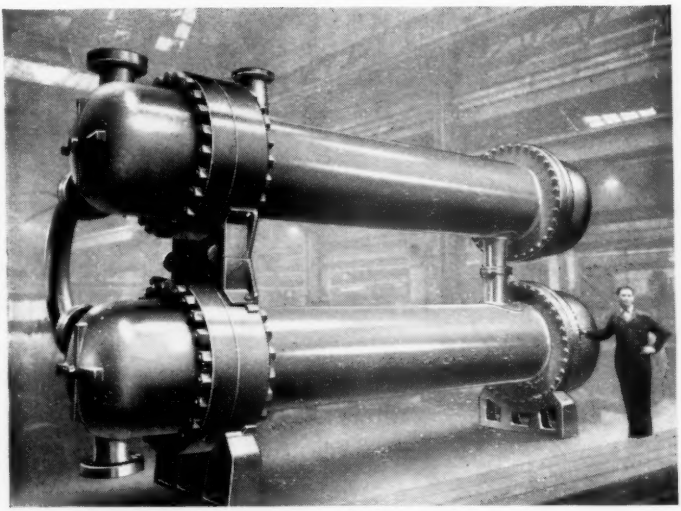

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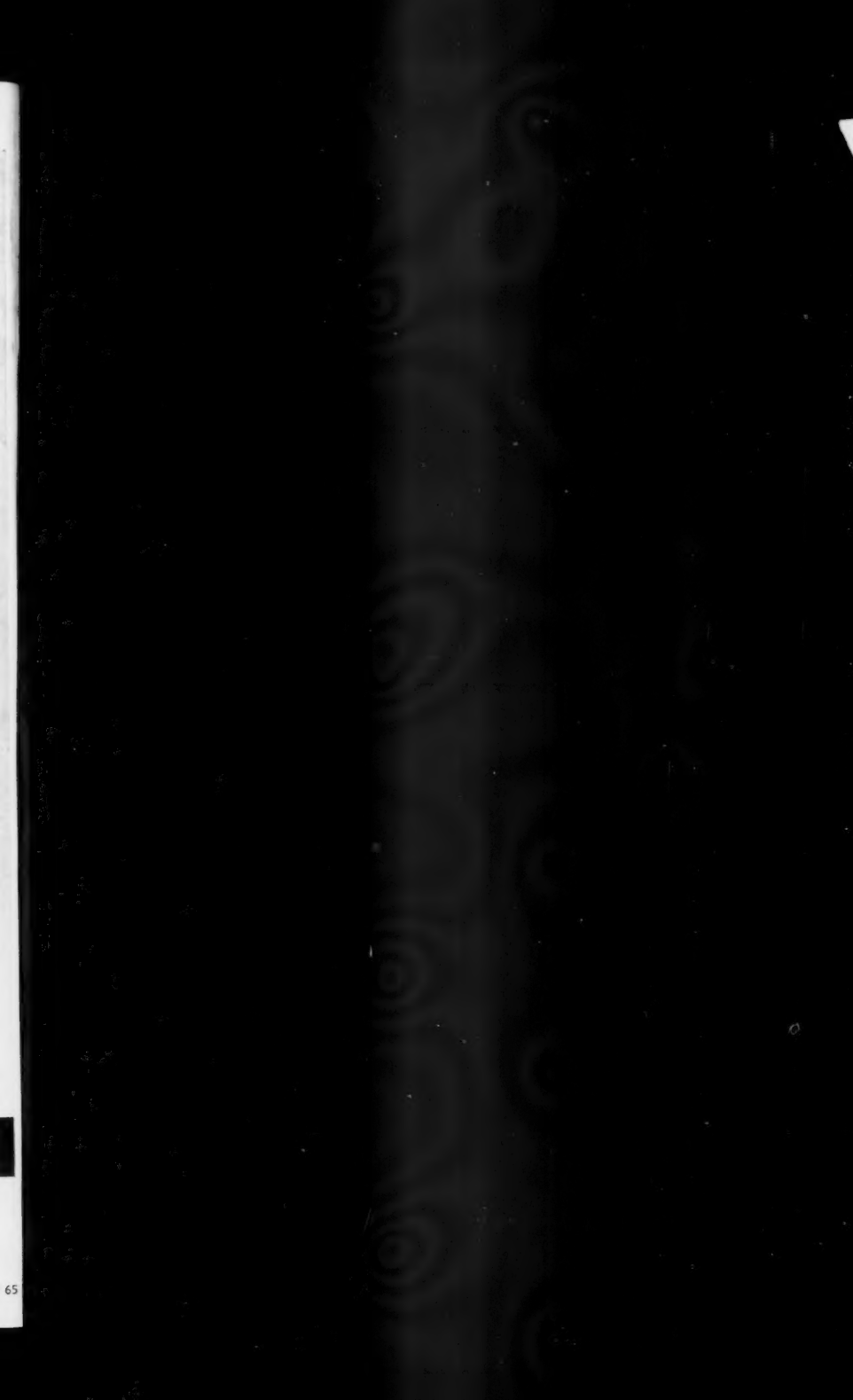
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